PACK RATS'

CHEESE BITS

PACK RATS

CLUB CALL: W3CCX

MT. AIRY VHF RADIO CLUB, INC.

MT. AIRY VHF RADIO CLUB., "THE PACK RATS", PHILADELPHIA, PENNSYLVANIA W3CCX
NET FREQUENCIES: 50.125, 144.150, 222.125, 224.58/222.98, 432.110, 903.100, 1296.100 MHz
AFFILIATED CLUB: AMERICAN RADIO RELAY LEAGUE ARNS

Meetings: Third Thursday of each month at 8:00 PM
Southampton Free Library, 947 E. Street Road
Southampton, Pennsylvania 19866

VOLUME XXXIII OCTOBER 1991 NUMBER 10

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THE PREZ SEZ

As a young ham some years ago, I can still remember the thrill of my first VHF DX contact. The date was 1964, and with my super station which consisted of a Heath "TWOer", I managed to work W2NSD on 73 Mountain. I believe that this hooked me into my long stay on the VHF and microwave frequencies. As club members and VHF enthusiasts we all, to some degree or another, want to get satisfaction from our hobby. This satisfaction can take many forms... some may strive to win a contest, others may seek to set a VHF DX record. For others, the construction of equipment which meets their needs and exceeds the performance of commercial equipment brings great pride and joy. But for many, great satisfaction simply comes from the thrill of a QSO on a new frontier or their first QSO on VHF/UHF. Here on the East Coast, we are blessed with a dense population base and with shear numbers of VHF/UHF enthusiasts, many diverse ideas on how to achieve our goals are available. Folks out in the Midwest aren't as fortunate, as I can attest having spent 6 years of my ham career in Dodge City, Kansas. My nearest VHF neighbor was located 50 miles away! In that environment, the die-hard VHFer will find other ways to enjoy the bands. This may be the reason behind all of the interest in microwave grid-hopping and EME.

To make this long story kind of short, I had an opportunity to hook a new ham last weekend. Ron has one of those new no-code technician licenses and I invited him over to watch and help me operate the September VHF QSO Party. I decided to let him help set up and operate the 3456 MHz gear and we used his 2 meter HT as an IF when we worked N2CEI at about 20 miles away. Ron felt a great deal of accomplishment in this contact since he has a microwave technical background with AT&T and understands the difficulties to overcome at these frequencies. He later told me that he is ready to get off of the FM repeaters because, in his own words, "this is where the real excitement is". How about the rest of you? When did you last capture the thrill of a new band? It may be just what you need.

I'll see <u>all of you</u> at the Conference and Hamarama. <u>We need 100% participation!</u>

73, William T. Murphy, W0RSJ

EMERGENCY BLOOD REQUIREMENT: DONATED BLOOD IS NEEDED FOR A FAMILY MEMBER OF PACK RAT JOHN KEDZIORA, KD3VI. PLEASE CALL JOHN AT 215-343-9272 IF YOU CAN HELP. THANK YOU.

Pack Rats CHEESE BITS is a publication of the Mt. AIRY VHF RADIO CLUB, INC. Philadelphia, Pa. and is published monthly.
SUBSCRIPTION RATE - $7.00 PER YEAR

We operate on an exchange basis with other publications. Anything that is printed in CHEESE BITS may be reprinted, unless otherwise stated, provided proper credit is given.

DEADLINE FOR ARTICLES AND SWAP SHOP IS THE 20TH DAY OF THE MONTH. NON-COMMERCIAL SWAP SHOP ITEMS - FREE OF CHARGE.

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PACK RAT 220 FM REPEATER - W3CCX/RPTR
222.98/224.58 MHz, CHURCHVILLE, PA

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MONDAY NIGHT NETS	NET CONTROL
7:30 PM - 50.125	W3CL + K3EOD
8:00 PM - 144.150	W2EIF
8:30 PM - 222.125	WC2K
8:30 PM - 224.58/R	K3ACR
9:00 PM - 432.110	WA3AXV
9:30 PM - 1296.100	WA3NUF
10:00 PM - 903.100	N3AOG

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KB3XG, JOHN SORTOR
(215) 766-2643

HAMARAMA CHAIRMAN:
K3EOD, AL BOBLITT
(215) 742-3312

HAMARAMA 1991

TO ALL MEMBERS OF THE MT. AIRY VHF RADIO CLUB... ALL PACK RATS:

EACH AND EVERY MEMBER OF THE CLUB IS DESPERATELY NEEDED TO ASSIST IN THE EXECUTION OF HAMARAMA 1991. UNDERSTAND THAT WE HAVE MADE A MAJOR LOCATION MOVE AND MANY UNEXPECTED LOGISTIC PROBLEMS ARE ANTICIPATED. UNDERSTAND ALSO THAT THE CLUB HAS COMMITTED A LARGE FINANCIAL INVESTMENT WHICH CAN RESULT IN A PROFITABLE GAIN FOR THE CLUB OPERATION OR, JUST AS QUICKLY, FINANCIAL TRAGEDY.

WE NEED THE ABSOLUTE DEDICATED COMMITMENT OF EVERY MEMBER OF THE PACK RATS TO MAKE THIS HAMFEST WORK SUCCESSFULLY. IF YOU HAVE NOT VOLUNTEERED YOUR HELP AND SERVICE, PLEASE DO IT NOW. DON'T BE RESPONSIBLE FOR A FAILURE. CALL A CREW LEADER TODAY AND OFFER SOME ASSISTANCE. EVERYONE IS NEEDED TO GET THE BALL ROLLING AT THE NEW LOCATION.

CHAIRMAN AL'S PLAN OF ATTACK:

SIGN CREW: PAUL DREXLER, WB3JYO 215-598-3934 or 215-441-1402. All members of the sign crew and any helpers will meet at the Route 70 and Cornell Ave. entrance of the Park on Saturday evening after the VHF Conference, approximately 10 PM, to install signs and traffic control equipment.

NIGHT TIME PARKING CREW: RICK CONNOR, WC2K 609-268-0736 or 609-783-4808. Rick and crew will arrive at the Park at 3:00 AM to begin parking sellers in proper areas. Some ticket sellers will be needed to work with this crew.

TICKET SELLERS AND PARKING CREWS: TICKETS - TONY SOUZA 215-847-5017, PARKING - GARY HITCHNER 215-539-6409. This crew should plan to arrive at 5:00 AM to join the night-crew handling buyers and sellers. Relief personnel will be needed for short time blocks throughout the morning. Get an assignment from crew chief now.

REGISTRATION CREW: PAT CAWTHORNE 215-572-5289 or 215-699-7051. Install registration tent and club table. Coordinate set-up of Cherry Hill Emergency Management truck with talk-in and PA system operators. Begin set-up at 5:00 AM.

BREAKFAST FOR ALL CREW MEMBERS: Breakfast of your choice will be provided by the Pack Rats at the Diamond Restaurant, on the Race Track Circle, at 4:00 AM. Crews will depart from restaurant at 4:55, drive across the road to HAMARAMA site.

HAMARAMA CHAIRMAN: To receive an immediate, much needed assignment, contact Chairman Al Boblitt, K3EOD 215-742-3312 **NOW!**
LET'S MAKE THIS THE BIGGEST AND MOST SUCCESSFUL HAMFEST THE CLUB HAS EVER HELD!

TID BITS

- If you have not received your Pack Rat baseball cap for January 1991 VHF Sweepstakes participation, Bob, WB2YEH will have them at Hamarama for distribution. Pick yours up at the club table.
- The Foundation for Amateur Radio is pleased to announce that 38 winners have been awarded scholarships. Individual awards range from $500 to $1,000. For a list of the 1991 scholarship winners, SASE to Cheese Bits editor.
- Received a KH6-land post card from Pack Rat K2EVW. Rich sez "howdy" to the club but does not explain what secret mission he's on.
- Your editor believes that the Hamarama game plan is so important that Paul's Propagation Report has been deleted this month. 'JYO's column will resume next month. By then Paul and Naomi will have officially "tied the knot". Best wishes to the new Drexlers!

CALENDAR OF COMING EVENTS

By Harry Brown, W3IIT

OCTOBER

2 — CRRL Fall VHF/UHF Sprint on 432 MHz. Starts 7 PM on Oct. 2 and continues to 12 AM on Oct. 3. Operate a maximum of 4 hours. See Sept. QST page 88.

5 — **Mt. Airy VHF Radio Club** hosts the Mid-Atlantic VHF Conference at the Woodland Fire Hall, Route 38 and Beechwood Ave., Cherry Hill, NJ. All day affair with on-location seminars, hospitality, lunch, and dinner. Conference registration begins at 8:30 AM, first speaker at 9:00.

6 — **Mt. Airy VHF Radio Club HAMARAMA** hamfest at the Garden State Park, Rt.70 in Cherry Hill. Gates open to sellers at 3 AM. Buyers and brousers admitted at 7AM. Breakfast for work crew provided at Diamond Diner, Race Track Circle, Rt.70 in Cherry Hill at 4AM.

8 — CRRL Fall VHF/UHF Sprint on 222 MHz. See Sept. QST page 88 for details.

10 — **Pack Rat Board of Directors meeting.** Listen to nets for location.

14 — Columbus Day

14 — CRRL Fall VHF/UHF Sprint on 144 MHz. See Sept. QST page 88 for details.

17 — **Pack Rat general membership meeting** at the library, 8:00 PM.

20 — Penn Wireless Assn. Hamfest in Bensalem, Pa.

26-27 — ARRL International EME Competition, 1st of 2 weekends. See Sept. QST page 87 for rules.

26 — CRRL Fall VHF/UHF Sprint on 50 MHz. See Sept. QST page 88 for details.

27 — RF Hill ARC Hamfest in Sellersville, Pa.

OCTOBER 5, 1991 PACK RAT VHF CONFERENCE SCHEDULE OF SPEAKERS

by John Sortor, KB3XG, Chairman

0900 : Paul Drexler - "High Level Mixer Design" Short lecture followed by equipment demonstration.

1000 : Ray Stahl - "Microwave Multiplexing/EMP" Multiplexing microwave signals and the effects of EMP on VHF/UHF/Microwave equipment.

1100 : Emil Pocock - "11 Years of Sporadic E" Collected data and theoretical predictions concerning E-Skip propagation.

1200 : Lunch

1300 : Dr. John Mulholland - "Satellite Communications" Satellite communications from its inception to the present.

1400 : Joe Reisert - "Antenna Matches" Demonstration of the hard ways, and right ways to match an antenna.

1500 : Dr. Jim Breakall - "Computer Aided Antenna Modeling" A demonstration of the state-of-the-art software for VHF antenna design.

DIRECTORY CHANGE OF ADDRESS:

KE2OI, JOHN C. GROVE
487 WHEATON AVENUE
BAYVILLE, NJ 08721
908-269-0520

SWAP SHOP

WANTED: Mixers for 5760 MHz and 10 GHz; HP 618 generator or similar to cover 5760 MHz.
CONTACT: Larry Filby, K1LPS
RFD #2 Box 125
St. Johnsbury, Vt. 05819

COMMERCIAL AD

JANUARY 1992 VHF SS CONTEST

by Phil, WA3NUF, Chairman

It's time to start thinking about the upcoming January contest. Last year, the Packrats succeeded in re-capturing the 1st place Unlimited Category gavel. The fact that we had to re-gain our customary place in the standings proved two things... first, we can still outdistance all competition by a wide margin, and second, that we can just as easily beat ourselves by not contributing to the club effort and assume the other fellows will carry the load. The last few years have shown without a doubt no matter how high a score we come up with - WE ONLY WIN IF WE ALL PARTICIPATE. Take some time and review your operation in last years contest. What went wrong? What went right? What would you change if you had the chance? Right now is the time to lay the ground work for a big improvement in January.

Remember 220 MHz low end activity has moved to 222.1 - it's time to re-crystal the rig. Anyone need help? There is still plenty of time to add a new band to your contest arsenal. 903 and above activity is growing every year and NO-TUNE transverter kits have made the microwaves easier than ever. For the more ambitious, the rumblings about 5760 projects are getting louder every week.

In the weeks ahead, team captains will be selected; please give them your support or better yet, get involved and help someone in the club with a new project. Contest weekend: January 18-20, 1992. Remember, it's up to you in '92.

VHF/UHF ACTIVITY NIGHT PROPOSAL

It was "resolved that the Eastern VHF/UHF Society recommends amateurs adopt the following operating convention for the VHF/UHF/SHF amateur bands" at the recent conference in Nashua, NH. This is a schedule for weekly concentrated amateur operating activity: (activity nights, all times local time)

144 MHz - Mondays 2000-2100	222 MHz - Tuesdays 2000-2100
432 MHz - Wednesdays 2000-2100	903 MHz - Thursdays 2000-2100
1296 MHz - Mondays 2100-2200	2304 MHz - Tuesdays 2100-2200
3456 MHz - Wednesdays 2100-2200	5760 MHz - Thursdays 2100-2200
10368 MHz - Mondays 2200-2300	**144.320 MHz liaison for higher bands**

THE W3CL ROAST REPORT
by Al Boblitt, K3EOD

On Saturday September 21, 1991, 97 people met in Trevose, Pennsylvania to honor Harry Stein, W3CL, a man who has given over 60 years of his life to the betterment of amateur radio and the last 35 years to the foundation and management of the Mt. Airy VHF Radio Club (The Pack Rats).

Harry's guests started arriving at the San Remo restaurant as early as 11 AM and as more and more people arrived, old friendships were re-kindled.

At approximately 12:20, Harry and Sylvia arrived, transported by Ernie W3KKN and his wife Bert, W3TNP. Harry was under the pretense that he would be attending a small luncheon being held by a couple of past presidents of the club to celebrate the club's 35th anniversary.

When Harry entered the room, he was greeted by a standing ovation. Harry was led to the head table by George, W3HK who was the master of ceremonies. Harry was then greeted by some surprise guests who had been hidden from the main room. One by one the surprise guests greeted Harry, shocking him over and over. First was his daughter Marsha, WA3TEM, then his two grandchildren Joshua and Rebecca, and Marsha's husband Fred who had spent the last 36 hours flying home from Singapore to attend the roast. Harry was then greeted by his brother and sister-in-law Dan and Marjorie Stein. The next guest was Harry's daughter Florene who flew in from Albuquerque, New Mexico, and the final special guest, Harry and Sylvia's friend Roberta Bondar, a Canadian female astronaut who had flown in from Toronto.

An invocation was offered by Caesar W2SVV, and then a wine toast was given by El K3JJZ. Following, everyone introduced themselves, Pack Rat style. Dinner was served followed by a birthday cake to celebrate Harry's 80th and then an anniversary cake to celebrate Harry and Sylvia's 52nd. A number of letters from people who could not attend this gala event were read by Marsha and Roberta. Then Prez Bill W0RSJ presented certificates of achievement to Harry W3CL, Ernie W3KKN, Elio W3RZU, and Lenny W2GGB (Len could not attend due to illness). These four men are the remaining founding fathers of the Mt. Airy VHF Club.

A number of Harry's friends then proceeded to roast him. Many unknown facts about Harry were exposed! The roasters were: George W3HK, Ed W3AJS, Ed W2SPV, Walt WA3AQA, Bill W0RSJ, Al K3EOD, Randy WB2SZK, Dr. David Finkelstein, Loretta Cutler (XYL K3GAS), and Roberta Bondar. Harry was then presented with the following gifts: VOICE KEYER de the Pack Rats, ROLEX WATCH de Ed Kephart, THE RAT (string art) de Dave Zimmerman, CARRY-ALL BAG and MAPLE SYRUP de Roberta Bondar, W3CL CHICKEN LIVERS HAT WITH CHICKEN LIVERS ANT ANTENNAS de Al Boblitt, CHARACTERIZATION OF HARRY drawn and framed by Lynn Whitsel (XYL WA3AXV). Ed Kephart also provided all guests with a memo pad of $50 bills with Harry's picture replacing Franklin's. Harry was permitted to make some comments about the affair. One was that he was totally surprised and shocked, and had no idea about the roast. Thanks for keeping it a secret gang! Afterwards, Harry greeted all his guests. A good time was had by all in attendance: Harry Stein W3CL and Sylvia,

Pack Rats: KF6AJ + YL, W3AJF, WA3AQA + XYL, W2AXU + XYL, K2BPP, W3CIL, W3CXU, N3CX + XYL, W3CJU, K3DLS, K3DMA, WA3EHD, W2UIF + XYL, K3EOD, W3GXB + XYL, WB3HHO, WA3HIT + XYL, W3HK + XYL, W3HMU, W2HX, W3IIT, K3IUV + XYL, K3JJZ + XYL, WB3JYO, WC2K + XYL, W3KKN, NF2L, KA3MGB + XYL, W3NSI + XYL, WA2OMY + XYL, W0RSJ, WB2RVX + XYL, W3RZU, WB2SZK, WB2VLA, KB3XG, WA3YUE + XYL.

QCWA Members and friends: W3AJS + friend, W3ALR, W3DIP, W3DVC, W3EY + XYL, W2FDE, KA3IDE, W3JGC, W3KDB + XYL, W3OOJ + XYL, W2PAU + XYL, KA3PGC, W2QLP + XYL, W2SPV, W2SVV + XYL, WA3TUC + XYL, W2URE; Marsha, Fred, Joshua, Rebecca, Florene, Dan, and Marjorie Stein; Dr. and Mrs. David Finkelstein, Loretta Cutler, John Pettit, Stanley Vekeris, Del Sutton, Ray Sutton, and Roberta (Bobbie) Bondar.

TWT'S AND KLYSTRONS: HOW THEY WORK AND HOW TO USE THEM- PART I

by Dave Hallidy KD5RO/2

INTRODUCTION

Travelling Wave Tubes (or TWTs as they are commonly referred) and Klystrons have been the mainstay of military and commercial microwave RF power generation for over four decades. These days, as more and more companies are removing microwave radio links from service and replacing them with fiber optic cable, hamfest fleamarkets are loaded with great deals on surplus TWTs and klystrons. These units can be very useful for generating high power in the amateur microwave station. In this series of articles, I will briefly discuss the history of the development of these tubes. I will also cover the theory behind their method of power amplification, what to look for in a TWT or klystron at the fleamarket, precautions to take when buying or using them, a general idea of what to expect to pay for them, and what to expect from amplifiers using these tubes.

A LITTLE THEORY

As early as the 1920's and 1930's, RF engineers realized that the upper frequency limit of a conventional gridded vacuum tube amplifier's performance is determined by "transit-time effects". That is, as the wavelength of the signal to be amplified gets shorter, the physical spacing between tube elements (cathode and grid in particular) becomes a significant part of a wavelength and the electrons can't move between elements in zero time. At some frequency then, a given tube becomes unable to amplify because when a signal is applied to the grid, these effects "confuse" the electron stream to the point where the gain is reduced to zero. Further complicating the problem is the fact that interelectrode capacitance in the tube becomes more significant as frequency increases, to the point where the capacitive reactance between elements of the tube will effectively "short out" the high-frequency signal. In the late 1930's the need to push higher in frequency increased, due mainly to the military's requirement for a system which could be used to detect the presence of enemy aircraft and to allow pinpoint accuracy when conducting bombing raids (RADAR). Many engineers (the Varian brothers, Bill Eitel and Jack McCullough among them) worked to design tubes which exploited transit-time effects to increase, rather than decrease, amplifier gain. The tubes which are the subject of this article all amplify by transferring energy from power supply to output by the controlled slowing of a high energy electron stream (called VELOCITY MODULATION). The faster an electron is moving, the more energy it has. In slowing the stream down, the electrons are forced to give up some of their energy. TWTs and klystrons are similar in that they both use this principle of velocity modulation to cause amplification, but the way each performs this function is very different.

THE TWT (TRAVELLING-WAVE TUBE)

The most popular of the microwave amplifier tubes is the Travelling Wave Tube (or TWT). This tube was not the first invented, however- that credit belongs to the klystron, discussed later. The first TWT was successfully tested during the Second World War. It operated at about 3300 MHz and exhibited a gain of 8dB with a 13dB noise figure. Credit for its invention goes to Rudolf Kompfner of the Nuffield Laboratory Physics Department of Birmingham University in England. John Pierce of Bell Labs is credited with development of the mathematical theory explaining TWT operation. In 1947 these two joined forces to continue TWT research. Today, TWTs are manufactured primarily as transmit power amplifiers, though in their early days, they were also designed as high gain, low-noise (relative to the other devices available at the time) receiver preamplifiers. They are found surplus today in power ranges from 10mW (the old receiving-type TWTs) to many hundreds of Watts. TWTs have very wide bandwidth and usually show considerable gain over as much as an octave of frequency (2-4 GHz, 4-8 GHz, 8-12 GHz, etc.). For the amateur, this is a particularly useful fact, because it means we can use one amplifier for more than one band. As a matter of fact, most TWTs can be used outside their design frequency to produce useable power. For example, I have seen a 1-2 GHz unit rated for 100 Watts output produce over 50 Watts at 3.456 GHz, and a 6 GHz unit designed for multi-channel use produce nearly 50 Watts at 5760, 40 Watts at 3456, 10 Watts at 2304 and about 4 Watts at 10,368 MHz! This is because, though the structure of a particular tube is such that it is designed to have a specific amount of gain and power output over a specified range of frequencies, the fact is, the elements of a TWT are not resonant at any frequency. This means that a TWT can still produce significant output power up to as much as one octave higher or lower in frequency than the tube was designed for. Usually, some adjustment of the beam voltage is necessary to achieve best performance of a TWT outside its design frequency range. Input drive requirements will likely change as well.

HOW TWT'S AMPLIFY

A TWT is basically similar to a CRT (Cathode Ray Tube), in that there is an electron gun which generates a high energy stream of electrons and a magnetic structure through which the beam passes and is altered. In a TWT, the electron beam is actually used to do work (produce RF power), losing energy to the output coupler as it passes through the magnetic structure (in a CRT, the magnetic structure merely distorts the beam without changing its energy level). The unused electrons in the TWT beam are collected after they leave the magnetic structure and are returned to the power supply. The CRT beam strikes the face of the tube where it gives up its energy by causing the release of photons, causing the screen to illuminate. Figure 1 illustrates a generalized example of TWT structure. At the left of Figure 1 can be seen the electron gun. The Cathode forms a very dense cloud of electrons which are accelerated towards the Anode by virtue of the great potential difference between the two elements. There is a hole in the center of the Anode and a portion of the accelerated electrons pass through this hole and into the "RF" portion of the TWT (also referred to as the Slow-Wave Structure). They are further greatly accelerated at this point, because the Helix and Collector are both greatly positive with respect to the Cathode (typically 2-10 kV Helix/Collector potential, depending on the tube's power and the frequencies to be amplified). As the beam accelerates toward the Collector, it passes through the Helix. The Helix is a long spiral of thin wire, similar to a "slinky". RF is injected into one end of the Helix, and amplified RF is extracted from the other end. The beam travels through the middle of the Helix, hopefully with little or no contact between the two. A series of magnets is placed around the circumference of the tube. These magnets are carefully positioned around the tube during construction, and their purpose is to keep the beam well-focussed as it passes through the Helix, for two reasons: first, tighter focussing of the beam causes the tube to amplify with greater efficiency, since more of the beam will remain intact as it travels through the Helix; second, and maybe most importantly, the Helix is a very fragile structure made of extremely thin wire. It is not capable of dissipating much power and too much current flowing in the Helix (caused by spreading of the beam) can cause irreparable damage to it, making the tube unusable. With the beam running through the Helix, we can now apply a weak RF voltage to the Input Coupler, which can be coaxial or waveguide, depending on the tube and frequency of operation. When this voltage is applied to the Helix, the velocity of the electrons slows down from the speed of light to some lower speed which is dependent upon the dimensions of the spiral of wire which forms the Helix. If slowed sufficiently, the RF signal will match the velocity of the electrons travelling in the beam. The field around the Helix generated by the RF signal will then interact with the beam, causing some of the electrons in the beam to accelerate (during the positive half cycle of the RF signal) and some to be retarded (during the negative half cycle). The beam is thus velocity modulated and bunches of electrons are formed which now travel as the beam. When these bunches interact with the next section of Helix (and the RF field associated with it), the same thing happens all over again. Each time this interaction occurs, the energy transfer from the beam to the signal is greater and thus, amplification occurs. When this amplified signal reaches the end of the Helix, an Output Coupler extracts the signal and delivers it to the load. The Slow-Wave Structure is frequency independent to a large degree (except for input and output matching); however, amplification in the tube is greatly voltage-dependent, since the initial velocity of the electron beam is set by the beam voltage and must closely match the velocity of the slowed RF signal travelling in the Helix. One other portion of the Slow-Wave Structure deserves mention. That is the Attenuator shown in the center of the Helix structure in Figure 1. This is a very important part of the tube, as it reduces the overall gain of the tube to prevent undesired oscillations caused by the input portion of the Helix "seeing" the large signal appearing at the output. The beam still retains considerable energy after travelling through the Slow-Wave Structure and it is the job of the Collector (shown at the right end of Figure 1) to "catch" the remaining portion of the beam and return it to the power supply. Most TWTs are designed to operate with the Collector at ground potential and the Cathode at maximum negative voltage.

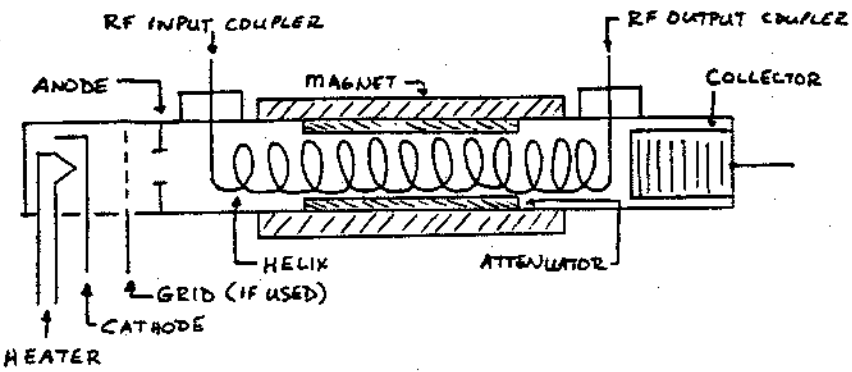

FIGURE 1. TYPICAL HELIX-TYPE TWT CONSTRUCTION

Figure 2 shows a generalized diagram of an amplifier incorporating a TWT. Since it is the function of the RF field in the Helix to modulate the electron beam, a well-regulated beam

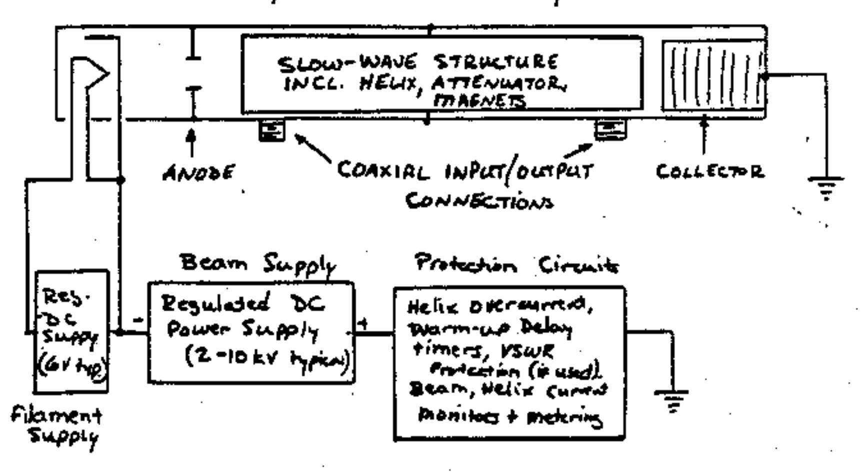

FIGURE 2. TYPICAL TWTA

supply is usually incorporated in a TWTA (Travelling-Wave Tube Amplifier). This is done to prevent supply voltage fluctuations from modulating the beam, which would cause changes in gain and output power. As mentioned before, the Collector and Helix (and sometimes the Anode) are operated at DC ground potential. This facilitates making connections to the Helix using coaxial cable (the shield of which is usually grounded) and simply requires that the Cathode be operated at B-. Some TWTs incorporate the use of a Grid in the electron gun to control the beam- usually the Grid is operated at a slight negative potential with respect to the Cathode, and complete turn-on and turn-off of the beam can be accomplished by varying this voltage only slightly. If you find a TWT or TWTA with a Grid terminal, this is a great way to turn the beam on and off during transmit and receive periods. TWTs inherently generate a lot of broadband noise and there is nothing worse than trying to listen for a weak microwave signal which is lost in TWT noise- turning the beam off during receive periods by controlling the Grid is one way to eliminate this problem. As I mentioned earlier, a TWT or TWTA is specified to meet a certain set of design criteria. This specification is met with the beam voltage set at one level and any signal (or group of signals) applied within the frequency range of the tube, at the specified input level, will generate the specified output. It is very unusual for the "broadband" beam voltage setting to be optimum to produce maximum gain and output at any particular frequency. Since we amateurs rarely (if ever) need to occupy the entire operating range of a particular TWT, we can adjust the beam voltage to produce greater output from the tube, with greater gain, on just one frequency. Most commercial TWTAs have beam voltage adjustments built in to allow this optimization. For example, I have a TWTA, built in the mid-sixties for the military, which is specified at 100 Watts output across the range from 2-4 GHz, with 30dB gain. This specification is met with the beam voltage set at 3000 Volts. By injecting a signal at 2304 MHz and adjusting the beam voltage carefully to 3050 Volts, I now can achieve 160 Watts output (2dB greater than spec) and with 34dB gain, which means less drive is required from my transverter. At 3456, I can again optimize the tube's operation by adjusting the voltage to 3275 Volts. The output isn't quite as high as at 2304 (140 Watts), but the gain is over 36dB. I mentioned earlier that a TWT could usually be used well outside its design frequency range. Using the same example, at 902 MHz (over 1000 MHz below the specified lower frequency limit!), I can achieve 100 Watts output by adjusting the beam voltage downward to 2850 Volts and driving the tube with about +24dBm. Obviously, the gain is falling off (down to 26dB), but the tube is still making real power, when driven with only 250mW. This amplifier also works at 5760 MHz, producing 50 Watts of output with 500mW of drive (20dB gain) and the beam voltage turned up as far as the adjustment on the power supply would allow, to approximately 3500 Volts. Not all TWTAs will do this, but the vast majority will- making the investment even better, as the unit can be used on many bands- in the above example the 33, 23, 13, 9, and 6cm bands, covering 2 1/2 octaves of frequency.

FLEAMARKET SPECIALS

Over the years, I've discovered an interesting fact about most TWTAs (complete amplifiers incorportating TWT, power supply and protection circuits) which are likely to be found at fleamarkets or surplus stores. They usually don't work, and thus can be purchased very cheaply. Interestingly enough, every TWTA I have purchased I have been able to make operational. The greatest majority of junked amplifiers don't have bad tubes, but rather have power supply problems. I mentioned earlier that regulated high-voltage power supplies are mandatory in a TWTA to prevent gain and output problems, also to prevent hum modulation of the RF signal. There is also always a circuit incorporated to prevent excessive Helix current from flowing due to overdrive or beam defocussing. Failures of the Helix overcurrent protection circuits, and to a lesser degree the high voltage regulators, are far and away the major reasons why TWTAs are scrapped. Other problems which I have observed are failures of the filament regulator (the filament voltage is usually DC and regulated, again to prevent hum modulation of the beam), failures in the time-delay circuitry (incorporated to prevent enabling the beam before the tube is sufficiently heated), and in older style amplifiers which appear to power up correctly but trip out due to Helix overcurrent, misalignment of the tube in its mount. Many of the oldest TWTs used solenoid-type electro-magnets around the tube to focus the beam, rather than the toroidal permanent magnets used today. Amplifiers using these older tubes incorporated adjustments to physically align the tube within the electromagnet for best focus of the beam. If the amplifier is jarred, the beam will likely be out of position and in contact with the Helix, causing shutdown. Realignment is necessary, but is very easily achieved.

One question which is frequently asked about fleamarket TWTs is: "How much should I pay for a surplus (probably scrapped) amplifier? I can't even tell if it works!" Well, the answer is simple- pay as little as possible! Seriously, the only amplifier I have ever paid more than 100 dollars for was a unit which I knew was brand new in the sealed box. The typical fleamarket price for a 30 year old TWTA of unknown origin and (apparently) good physical condition is probably in the $20-$50 range. Except at Dayton, where the same unit will be priced at ten times this value. I carry an ohmmeter to check the tube's filament and other elements for shorts or opens. I also have acquired a selection of catalogs published by the various TWT manufacturers to which I can refer for information on a particular tube or amplifier. These catalogs are of limited value since we are usually looking at equipment which has been discontinued for years, but they have helped out on occasion. I recently purchased an old Alfred TWTA which looked like a one Watt unit for X-Band (10 GHz). I suspected it probably didn't work, as the asking price was $20. I got it for $15, and when I looked it up in my old Alfred catalog, discovered it was a ten Watt unit. I plugged it in, and it worked immediately!

There are some rules of thumb that you can apply to get an idea of what that TWT or TWTA you're staring at is capable of in terms of output power. First, most Helix-type TWTs are fairly inefficient- typically 10-15% at best. So, the first thing to look at is the plate on the side of the tube (if it's there). This may or may not tell you the power, but at least should tell you the recommended beam voltage and current. If the beam voltage is 2700 and the beam current is 100mA, then the DC input power of the tube is 270 Watts. Applying our 10-15% rule of thumb, we see that the output is likely to be between 27 and 40 Watts. Since they don't make 27 Watt TWTs regularly, it's more likely to be a 20 or 25 Watt unit. Not a bad buy, since it probably has at least 30dB gain (fairly typical for power TWTs) and could be as high as 40 or 50dB. Another rule of thumb is the physical size of the tube. If it's really small and the claim is that it's a 100 Watt tube, don't believe it! The Collector of a TWT has to dissipate a lot of power, usually by attachment of a heatsink or blower. The Collector's ability to lose heat is dependent on these factors and its size, so if we consider the 10% rule of thumb again, then a tube rated for 100 Watts of RF output would have to lose 900 Watts of heat in the Collector. A small Collector cannot do this and so determines the minimum size the tube can have. Some very small TWTs were built as receive preamplifiers for use at the very high microwave frequencies- 24 to 100 GHz. Though they don't generate much more than about 10mW output, they should be considered if you want to experiment on these frequencies- all the current amateur DX records on these bands were made using power in the range of a few microwatts to a few milliwatts at the most. Dish antennas are the principal means of generating high levels of ERP on these bands and a few milliwatts from a small TWT is an easy way to get there. Also, these receiving type tubes have very high gain- 40 to 70dB is typical. The next question is: "How do I determine the frequencies over which the tube operates?" This is a bit trickier to answer. To a certain extent, you can get an idea from the type of input and output connectors on the tube. Most TWTs used below X-band use coaxial connectors (type N or TNC). Most tubes used above X-band use waveguide flanges. The problem is that the tubes which use SMA type coaxial connectors may be found at all frequencies from about 6 GHz to 26 GHz or so. If the tube has waveguide flanges on it, it's easy to figure out what band it was designed for. Just measure the guide opening and compare to a chart listing the standard flange sizes. Then you'll know. Tube size again comes in to play here as well. Generally, the longer the tube, the lower the operating frequency. This is because the Helix must be longer at a lower frequency to produce the same gain as one at a higher frequency. Beam voltage also can provide a clue as to frequency of operation. It takes more electron velocity to provide amplification in a TWT at higher frequencies. The moderate power (10-100 Watts) TWTs I have seen which operate in the lower microwave bands (1-4 GHz) have beam voltages in the 2-4kV range. Tubes in the same power class that operate in the 4-10 GHz range have much higher beam voltages, usually in the 4-8kV range. Accordingly, lower frequency tubes draw more beam current than their higher frequency counterparts. The bottom line may be, if the unit is available at a good price and looks like it might be the one you've been dreaming about, grab it, take it home and play with it. Even if not intended for the frequency you want to use it at, with enough patience and playing, you may be able to use it, or at least determine where it was intended to operate. One thing, above all, to remember when experimenting with TWTs and TWTAs- BE CAREFUL! Very high DC voltages are present, as are dangerous RF voltages. I'm not saying this to scare you away from this work, just to make you aware and to advise you to use care.

CONCLUSION

In this part of the series, I have discussed a little of the theory behind the operation of TWTs and klystrons. I focussed on the TWT and TWTA, how they are constructed and how they may be used in the amateur microwave station. I also discussed ways to determine the usefullness of a TWT that might be found in the fleamarket of your local hamfest. Part II will cover the klystron in the same detail as the TWT. It will also cover typical uses for these tubes in our stations and any special equipment that might be needed to use these very unique microwave devices to maximum advantage.

THANKS TO DAVE HALLIDY, KD5RO AND THE ROCHESTER VHF GROUP JOURNAL.

PART II NEXT MONTH.

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