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High-Power Traveling-Wave Tube YH 1041, a New Transmitter Tube for Satellite Radiocommunication

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More than a year has passed since conventional long-range communications systems operating over marine cables or shortwave and longwave radio paths were joined by the first satellite communications systems. In the near future, the application of the multi-channel approach to satellites will lead to their more widespread use in radiocommunication, especially for the following four primary applications:

Intercontinental and continent-wide links for the transmission of telephone conversations, teleprinter messages, data, and radio and television programs.

Communications within large countries still without a nationwide radio relay or cable network of their own, e.g. developing countries.

Expansion of existing radio relay networks in large countries, e.g. the USA.

Military radiocommunication, especially with mobile earth stations, in the frequency range from 7.9 to 8.5 ghz.

Used in radio relay networks the satellite acts as a repeater. Signals from an earth station are picked up by the satellite, converted to another frequency, amplified, and retransmitted to another earth station. The frequency bands 5.725 to 6.425 ghz (with preferred use of the band 5.925 to 6.425 ghz) and 7.9 to 8.4 ghz have been allocated for earth-to-satellite transmission and the bands 3.4 to 4.2 ghz and 7.25 to 7.45 ghz for satellite-to-earth transmission.

Since the great distance between earth stations and the satellite results in a very high path loss, the earth stations must be equipped with high-power transmitters. The power required per carrier may be estimated as follows:

Experience has shown a radiated power of 58 dbw[1] per voice channel to be sufficient. Using this figure as a basis of calculation, single-carrier operation with 120 channels and an antenna with a gain of 60 db calls for a final power stage with a maximal power (referred to 1 watt) of 58 dbw + 20.8 db (120 channels) + 5 db (increment allowing for bad weather and feed losses) −60 db (antenna gain), which corresponds to 240 watts.

On choosing the final power stage of the transmitter for earth stations

Satellite radiocommunication has hitherto been restricted to intercommunication between two earth stations, with each station transmitting and receiving a single frequency-modulated carrier. Klystrons or traveling-wave tubes were used as transmitting amplifiers. For small-band single-carrier operation, klystrons are equivalent to traveling-wave tubes in transmission performance, whereas in gain and operating costs they are superior. Broadband frequency-modulated signals such as frequency modulated television signals with a bandwidth of 40 Mhz, however, can only be boosted with a traveling-wave tube without serious distortion.

Transmission systems now under development will allow simultaneous intercommunication between several earth stations by way of a satellite. Each earth station must for this purpose be able to radiate several frequency-modulated carriers simultaneously, the various carrier frequencies being chosen in the 6-ghz directional radio band according to a frequency allocation established by COMSAT (**Com**munications **Sat**ellite Corporation). Carriers radiated from an earth station may be amplified either *in common* by way of a *single transmitter tube* or *individually* by way of a *separate tube* for each. Here again a broadband traveling-wave tube will be eminently suitable because only two tubes in all would have to be provided for standby operation and reserve. If narrow-band tubes were used it would be necessary in the case of operation with several carriers to assign to each carrier a previously tuned tube for standby operation and another as a reserve.

Used in earth stations, traveling-wave tubes further offer the advantage that more channels may be added to the communications system without greatly increasing the cost of the final power stage, and that the transmitting frequency can be changed very rapidly.

The transmitter power required for multi-carrier operation may be calculated with the aid of the rule-of-thumb formula already given. This means that, say, four carriers with 120 channels each will require a maximal power (referred to 1 watt) of 58 dbw (power per channel) + 20.8 db (120 channels) + 6 db (4 carriers) + 5 db (increment allowing for bad weather and feeding losses) − 60 db (antenna gain), corresponding to about 1 kw. To ensure low-distortion in four-carrier operation, the saturation power of the final power stage must be 4 kw, i.e. about 6 db above this maximal power.

The Siemens traveling-wave tube YH 1041 is now available as a broadband transmitter tube with a saturation power of 5 kw. Operated in the frequency range of 5.925 to 6.425 ghz with one or more carriers and stabilized operating voltages, the tube delivers average c-w power

1 The term "n dbw" means that the difference between a given power P and the reference power value 1 watt is n db (10 log $P/1 = n$), e.g. 20 dbw corresponds to a power of 100 watts.