munication is from about 1000 to 10,000 Mc. Even with huge horn-reflector antennas for transmitting and receiving, and low-noise masers for amplifying the faint received signals on the ground, very broad-band modulation systems will be needed to obtain acceptable signal-to-noise ratios. Since there is only one electromagnetic spectrum available for radio transmission, avoidance of interference between space systems and from terrestrial systems into space systems will introduce grave problems.

All things considered, it is by no means unimaginable that within less than a half-century the congestion in the microwave range will leave no room for further exploitation by space communication. What then may be imagined as the next transoceanic communication medium? In the fact of necessity, some way will be found to multiply frequency spectra at will through the use of cable techniques. Maybe the answer will be an adaptation of the overland waveguide system, or in other words, a "waveguide cable" with the whole band handled by one amplifier at each repeater point.

In the long run, a "sheltered" transmission medium is almost certain to win out over radio for both continental and transoceanic communication. In view of the ever increasing importance of communication to world affairs, it is fortunate that such promising ways of handling future demands are in sight.

A Short History of Electromagnetic Communications

JOHN W. COLTMAN FELLOW IRE

By the 1960's it appeared that electromagnetic communication systems had reached tremendous heights of sophistication. Starting with the crude noises of the spark gap, laboriously coded by hand from the alphabet handed down by the Phoenicians only a few millennia ago, the uses of the radio spectrum burst forth in the course of half a century to encompass a bewildering maze of services. Coded and voice messages were transmitted over all the world, radar beams scanned the horizons, information was brought back from transmitters deep in the reaches of space, radio was everywhere, and the last decade had culminated in the miracle of the nightly repetition, in millions of homes all over the land, of the Western.

But even so, the electromagnetic spectrum hadn't really been tapped. The services extended from about 20 kc to 40,000 Mc, a little over 6 decades, and the upper end of the band was wastefully squandered carrying television signals that from the point of view of information theory (to say nothing of the point of view of culture) were highly redundant. Beyond lay tremendous reaches in the frequency domain. From 10^{10} to 10^{13} cycles were the submillimeter waves and the far infrared, essentially a trackless waste, traversed by an occasional expedition which noted the nature of the area, but did not stay to colonize it. It contained, of course, half as many decades as all of the communication spectrum had exploited until that time, and in terms of information bandwidth was thousands of times larger. Its development was hampered partly by the opacity of the atmosphere, but more by the inability to apply in the tiny dimensions required the techniques characterizing longer wavelengths. This area was finally opened up from the other direction by extending the techniques originating in the optical region of the spectrum. Now here was rich territory indeed—a narrow slice of the electromagnetic spectrum originally occupying scarcely an octave, but possessing an overwhelming advantage in that it was here that man's own receptor, the eye, operated. This superb mechanism had a receiving aperture only a few millimeters in diameter, yet was capable of absorbing and classifying information at rates far in excess of those characterizing the communications systems of the sixties; indeed, the latter had succeeded in presenting to the eye only a tiny and crude imitation of visible scenes, and had used up the then available communications spectrum in huge gobs while so doing. It was in the optical region of the spectrum that physics had its early triumphs; indeed, it is fair to say that our modern concept of the physical world rests primarily on a foundation established in the study of the

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propagation of light and its emission by atoms and molecules.

It was through these latter phenomena that electronics and communications became part of, and, indeed, essentially took over and engulfed, the art of optics. The key to the operation was the use of cooperative phenomena among atoms. Now all of the power of the electronic signalling techniques was combined with that of conventional optics. The provision of stable local oscillators at optical frequencies, together with the development of nonlinear media made possible the conversion of frequency, with all its attendant advantages.

At the same time, the precise directional properties available with the new frequencies were exploited. A single "antenna" (that is, a lens) of the most modest dimensions was capable of receiving simultaneously from thousands of points in space, and of keeping each transmission separated into its own channel. The frequency discrimination was, compared with the prior techniques, fantastic—it being quite possible to contain in a single millihue (the number of millihues in a wavelength interval is defined as 1000 log λ_2/λ_1) in the orange, for example, about a quarter of a million of the old "television channels." The invention of the brilliator in 1972 made possible the amplification of weak images without destroying the phase information, and by the 1980's, most of the point-to-point communications networks were in the optical or suboptical bands. The time-sequential scanning of images was abandoned, and television broadcasts were carried throughout by optical techniques, the time phases and angular dependence of the waves being preserved, duplicated, and amplified wherever necessary in the system.

The tremendous success of the method of coordinated atomic radiation brought forth an intensive search for means to extend the technique to even higher energies. Gradually, there evolved mechanisms operating in the ultra-violet and X-ray regions, and while these have been restricted to certain aspects of space communications, they have, in principle, added to the spectrum another six decades. The introduction of quantum coding, in which the message is carried by high energy quanta, distinguished by slight variations in their wavelength, proved to be of great value in overcoming the natural background radiation of space.

As every school boy knows, the most exciting project of the new millennium came as a result of the discovery in 1989 of the nuclear transmissions from the neighborhood of Sirius. These gamma-ray emissions were detected by UN Observatory A36, operating in a 24-hour orbit and carrying a highly sensitive gamma-ray brilliator operating in the Mn^{54} band. The intelligent character of the transmissions was apparent rather early, and while they have appeared only at scattered intervals, sufficient Doppler observations have been made to establish the period of the orbit of the planet from which they came, and even to demonstrate the distortion of this orbit by the presence of the dark companion of Sirius.

In 1996, a team of engineers and scientists, with the aid of superconducting magnets producing fields in excess of 1 million oersteds, succeeded in generating coherent gamma radiation in directed beams. Since then we have been making periodic transmissions to Sirius. If, as appears probable, the Sirians were searching for a reply, they should by now have received most of the transmissions, which have a 9-year travel time. Two years from now, it is theoretically possible that we will receive their earliest reply, and the world is eagerly awaiting this first exchange, across the depths of space, between the 2 worlds now known with certainty to exist.

Before submitting the above contribution, the author asked an associate to read and comment on it. In response he received the following "antithesis" which is included here in the belief that it will provide readers with a sobering, as well as amusing, treatment of the same subject.
—The Editor

The Spectrum Problem—Looking Back From 2012 A.D.

E. A. SACK

It seems so simple, in retrospect, that the older members of the profession still refuse to completely accept the solution. That their supreme efforts to conserve bandwidth and to develop new portions of the spectrum were really unnecessary is a revelation from which complete recovery is impossible.

Late in the 1960's, a few nonconformists were proposing that the so-called spectrum shortage was an organizational rather than a technical problem, but their theories were largely ignored by the scientifically oriented communications agencies. The major premise of the nonconformists, that one should first determine whether information really needed to be transmitted, seemed so undemocratic that their clearances were subsequently lifted in the interests of national security.

The reader will recall that science was in high fashion during the quarter century preceding the second millenium. The importance of the professional scientist had grown to the point where a doctorate in physics was a prime political attribute and both of the presidents during the period 1972-2000 were Fellows of the AEC.

But the law of trend and counter-trend is universal and while the technologists labored night and day to find ways in which to transmit ever-increasing gobs of information to the public, to each other and to nobody in particular, the humanist gathered in non-NSA supported workshops to accumulate, in anti-scientific manner, the evidence that the spectrum problem was purely a matter of inadequate legislation. Their philosophy evolved into the now-famous Sideband Theorem which states, "Technological solutions to nontechnological problems are in quadrature to progress."

The journals of the humanists during the period show the development of their deliberations. For example, in 1980 they proved that all of the AM broadcast stations played the same 20 records 90 per cent of the time. Their proposal that only one national broadcasting station using only one 10-kc channel might do just as well received passing note.

A similar study of the television spectrum in 1982 indicated that 85 per cent of the TV programs broadcast by 521 stations on 126 channels contained but six basic program plots. It was proposed at the time that these plots be provided in a small local memory to the home TV fan who could select them at random for the amusement of the integrated family group.

A secret study of the communications needs of the national defense establishment was even more revealing. Eighty per cent of all messages had to do with orders which were countermanded by subsequent messages and hence never needed to be transmitted at all. The remaining 20 per cent dealt with information which would be ignored at the receiving end and was, therefore, 100 per cent redundant.

An interesting example of the thoroughness of the investigation of the humanists was the study of the Public Service spectrum needs. At the time one city was demanding 5 additional channels for its police radio; its average transmitting time on each of its existing channels was 1 minute per hour. A typical communication was: "Car 5 stopping for a sangwich." "Repeat Car 5." "Car 5 stopping for a sangwich." "Say again Car 5." "Car 5 stopping for a sangwich." "OK, Car 5 stopping for gas."

As time went on, the battle between those who felt that more spectrum space was needed, and those who felt that less information need be transmitted, grew bitter indeed. But the outcome is familiar to all. The Communications Act of 2008 ended the spectrum shortage. Its major provision, of course, is that all information be first transmitted to Washington by surface mail for review by appropriate committee. If approved, the message is transmitted over the National Transmitter in a priority determined by the priority review board. The completely redundant information which was formerly broadcast on radio and TV is mailed out on tape, to all who care, on a monthly basis.

Unemployment among communications scientists has been largely eliminated by increased need for mailmen. Military personnel who became surplus by the impossibility of a really worthwhile war under the system have yet to be completely absorbed by the economy, but the matter is receiving further study. Public Service officials have complained that they no longer know when Car 5 is out for lunch, but one executive committee has proposed that the cops be given dimes to call in from the pay phone behind the counter. This may work.

The Full Use of Wide-Band Communications

SIR NOEL ASHBRIDGE FELLOW IRE

All radio engineers have an ultimate goal in mind: the day when wide-band communication can always be established between any two points on the earth's surface with absolute secrecy. He looks to a future when distance, season, and time of day are immaterial, and the business man and the house dweller are able to enjoy all that wide-band communication could conceivably offer. With this ambition in view, a picture of things which might be done within the next fifty years can be roughly envisaged.

In the future the urge to convey unlimited information over the globe will be sufficient to free the enormous sums of money which are needed to solve the problem. The military needs it, business needs it, and the man in the street is always prepared to pay for more amusement.

The solution might even be dull, the piling of complexity upon complexity, in fact, the gradual harnessing of known methods into huge co-ordinated systems. But the outcome might help to balance up the whole lopsidedness of the civilized world. It is not only the accomplishment but what do we do with it that is the exciting prospect.

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