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DATE: June 15, 1974

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SUBJECT: Band-Generator Strategy

cc: Rod Carlson
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Harley Halverson

I want to acknowledge Harley Halverson's report on his "Strategy for a Communications Modem". It was pure coincidence that I began to see a lack of modern signal simulation for a variety of non-communication markets at the same time. Redesigning the 614-628 series to do all modern modulations in each band didn't have much class.

All types of radars, RPV's, Telemetry, secure communications, spread spectrum are in a new, evolving stage. The beauty of this approach is that it coherently addresses the combined markets of the band-oriented microwave business.

In addition, I think it may alleviate the need to build-in phase modulation or fast FM (chirp) into the 8671.

John

JM/cb

PROPOSAL FOR A NEW LINE OF "BAND" GENERATORS

There's a revolution going on in microwave systems above 1000 MHz and our signal generators and synthesizers aren't hacking it. I've tried to point this up in my recent E.W. and Digital Communications reports.

I guess the most important observation from those studies is the emerging commonality of systems. Signals are being generated and modulated at VHF, upconverted to microwave, filtered, passed through linear amplifiers and transmitted. Furthermore, it's not limited to communications. Radar, positioning systems, navigation, military secure comm and satellites are all using these techniques.

Therefore, I propose as HP's new Klystron generator replacement strategy, a new family of Modem-Driven generators which matches fancy modulation capability with the narrow (≈10%) band-oriented-applications requirements of the above markets. It would use the up-conversion principle.

Our expertise in filters, balanced mixers, and up-conversion (PMR-4) will be just what we need. The product line will be revolutionary, flexible, adaptive and completely appropriate to the microwave systems of the late 70's and 80's. It would finally give us some modern sophisticated signal simulation.

Briefly the family would consist of:

1. A family of cavity-tuned CW (mostly) generators.

    3:1 to 4:1 frequency coverage
    Counter readout and Ø-lock stabilized
    Good spectral purity
    1-18 GHz; to 26 GHz later

2. A family of modem units with broad modulation capabilities such as:

    Super flat FM or FDM
    Phase modulation up to 10MBIT
    Wide-band phase modulation (500 MBIT)
    Fast FM for chirp radar tests
    Digital frequency hopping (fast hop)
    Phase mod diagnostic head
    Group delay head
    New MLA modem, etc.
    etc.

3. A family of filters for applications bands

Applications bands ±2 IF
Family of tracking YIGS

I believe the feasibility of this up-conversion technique has been well-proved on the PMR-4 instrument. In its 20% band, superior signal up-conversion is achieved. Spurious, intermod and harmonics are 80 dB removed and double-up-conversion spaces harmonics out of band. I feel the same technique can be extended to beyond 18 GHz.

Moreover most of the communication systems themselves have used up-conversion for years. Radars are now going that way. Military comm are using encoding modems, etc. Clearly, HP <u>can</u> build this generator family. Now for the <u>why</u>?

Here is a sampling of frequency allocations and representative types of systems to be using them:

BAND	BANDWIDTH	APPLICATIONS	MODULATIONS
960-1215	20%	DME/ATC	AM pulsed 1μS Gaussian
1670-1700	2%	Weather Satellite	QPSK
1.71-1.85	≈5%	Commerical, Bus., & TV	FDM, New QPSK
1.85-1.99			
1.99-2.11			
2.11-2.13			
2.13-2.15			
1.7-2.3	26%	Tropo, Satellite, Gov't space comm.	FDM, PSK
2450-2690	9	Satellite	Various
2700-3100	13	Surveillance/seaborne radars	AM Pulsed, 1μS
3.7-4.3	14	Links/Long Haul/ Satellite	FDM
4.4-5.0	12	Military Comm.	FDM
5.4-5.9	8	Missile fire control/guidance	AM Pulsed, fancy coding
5.925-6.425	8	Links, satellites	FDM
7.1-8.4	15	Military Comm,Satellites	FDM, going digital. 100 MBIT spread spectrum
8.4-9.5	12%	Fire control	Pulsed, 1μS, 1 kHz chirped Δ 60 MHz, 5μS
10, 15		RPV	28 MBIT spread spectrum

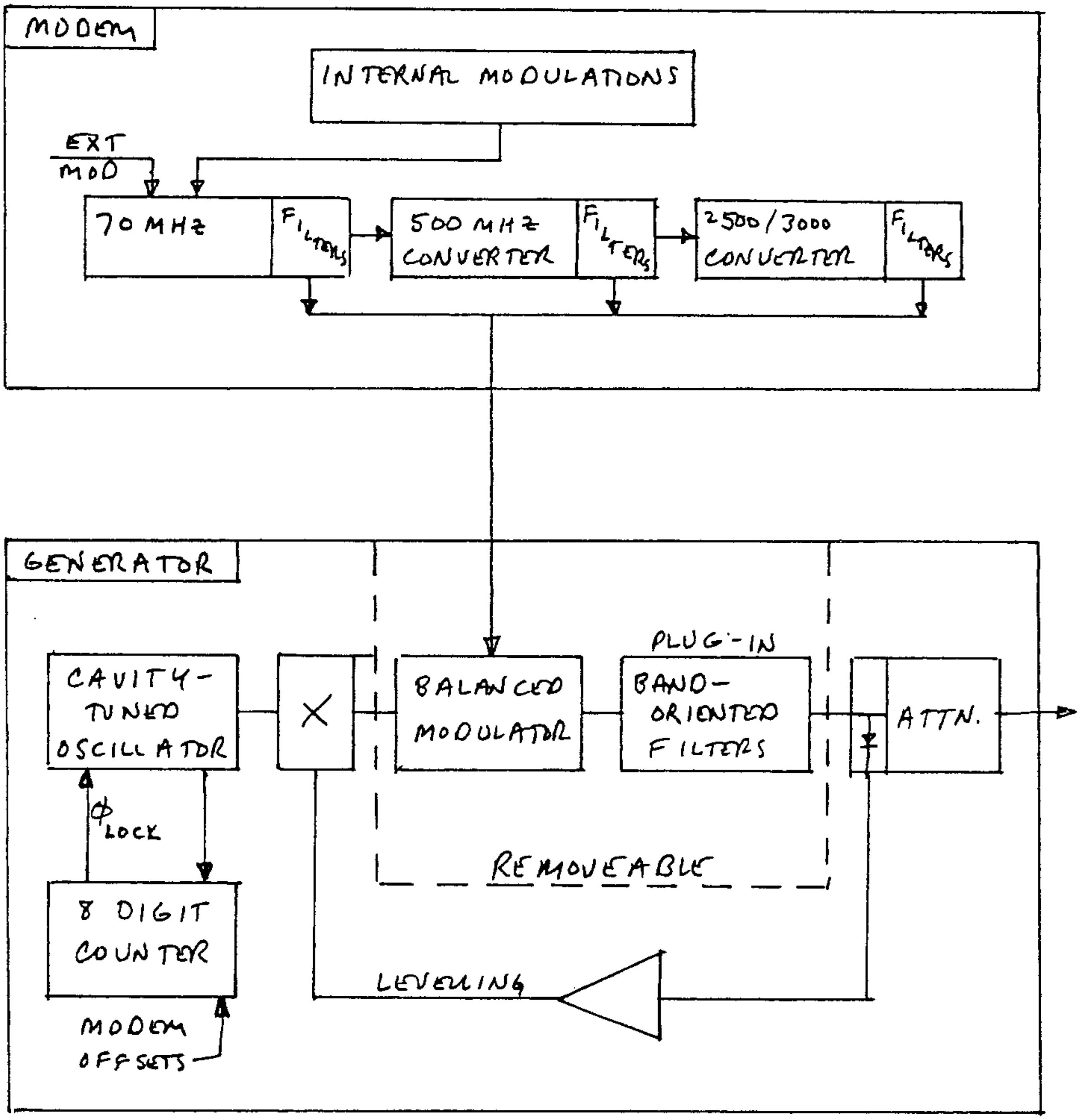
BAND	BANDWIDTH	APPLICATIONS	MODULATIONS
10.7-11.7	12%	TV/A.T.&T.	FDM
12.2-12.7	8%	Business Radio	FDM
13.2-14	6%	Radar, fire control	Doppler Nav. 9 kHz noise, Pulsed 1µS, 1 kHz and chirp
14.0-14.5	4	Satellite	QPSK
15.4-17.7	13	Radar	Pulsed, Chirped
17.7-23.6 2 bands	25	"Pole-Line"	QPSK 400MBIT
24.25-25.25	4	Mapping radar/"taxi" radar	Fast pulse, high resolution

The applications bands are all narrow. The modulations are widely varied, but getting more sophisticated all the time. It thus becomes very difficult to design general-purpose generators with enough modulation capability to meet all the various applications occurring through its 3:1 range.

By judicious design of the up-converting frequency and filters, harmonics and sidebands can be kept outside the use band. For example, Harley Halverson has shown that a 2900 MHz modem frequency might serve most military and commerical communication bands up to 11.6 GHz. Not only could general purpose modems be made, but highly-special-purpose types could be provided. (Group Delay-MLA).

The product concept would be as shown below. A cavity-tuned generator would serve as an L.O. to the modem. Modem electronics would probably be separate, but microwave parts would fit inside the generator. The band-oriented filters would also be plug-in.

BAND GENERATOR PRODUCT CONCEPT



The cavity is phase-lock stabilized and counted for 1 kHz or 10 kHz resolution. Automatic sensing from the modem offsets the counter so that the actual output frequency is displayed. The cavity output could also be used directly and would yield ≃10MW. When mixed and used with the modem, signal output would be approximately -10 dBm to -120 dBm.

Most applications of receiver testing can nicely live with -10 dBm and below. With this broad range of signal simulation, probably 80-90% of typical receiver tests could be run at those power levels. Occasionally 10MW might be desired for preselection reject, adjacent channel, or spurious response tests.

Some high level tests could simply switch to CW for 10MW. Others could possibly use a family of linear amplifiers with 10-100MW output. The amplifier set possibility was mentioned by Sandy Kakihana of the Technology Center. I think their actual usage would be small, although they could be easier to make since they could also be band-oriented. (15% BW).

The detail concept then looks as follows:

I. A Family of Cavity-Tuned Band-Oriented Generators

The new band-generator family would be designed to work directly with the modem family and thereby be an attractive package to customers. They would:

1. Be small-solid state-cavity tuned with 3:1 or 4:1 coverage.
2. Have direct frequency counting readout to 1 kHz.
3. Be Ø-lock-stabilized.
4. Permit offset of modem frequency to read application band directly.
5. Be designed to put some modem parts inside and pre-attenuator.
6. Have good CW spectral purity
7. Be designed for modular insertion of band-oriented output filters, or switchable output filters.
8. Be designed for L.O. service (10MW)
9. Have levelled output power

II. A Family of Applications-Oriented Modem Boxes

1. 70 MHz Phase Modem-Low Rate

   BPSK and QPSK
   Rates to 10MBIT or 20MBIT
   Adjustable Quadrature
   Noise Adding Feature for S/N vs BER Tests for frequency bands 20-70 MHz, 225-400 MHz (May need output filter switching)

The military IF standard for modems is 70 MHz as is much of the other phase-modulated communication and navigation. This one could follow the design described by Allen and Batson of RCA and NASA. (ICC-Seattle '73), attached.

2. 1500/2000 MHz or 2500/3000 MHz Phase Modem-High Rate

   QPSK or M-level phase
   Rates 10MBIT to 500MBIT or Gigabit
   Adjustable Quadrature
   Noise adding feature for S/N tests for frequency bands at 11, 14, 18 and 27 GHz.

Bell Labs is using 500-700 MHz for 270MBIT and N.E.C. is at 1500-1700 MHz for 400MBIT QPSK. I think a 1500 or 2500 conversion step is fine to 14 GHz. However the 18 and 30 GHz bands will be 3.5 GHz wide (probably 2 x 1.7 GHz or 3 x 1.2 GHz channels) so the up-conversion frequency for those bands maybe should be 3-4 GHz.

A laser satellite link with gigabit QPSK modulation used a 3.5 GHz modem frequency. This then modulated the laser with a polarization variable element. (Lockheed)

Possibly the model could have several switched frequencies depending on band and bit rates. We should try as much as possible to duplicate military and commercial IF assignments.

3. Fast FM (Chirp) and Frequency Hopping Modem

   Modem frequency, 1500 MHz
   ΔF for Chirp, 100 MHz in 5μS
   Analog-driven frequency hop: ΔF = 25 MHz to 100 MHz
   Settling time 1μS
   100 kHz steps
   10μS chip width

This modem would do most of the new pulse compression radar simulation. In addition it would do some of the frequency hopped spread-spectrum position systems such as the new RPV (Remote Pilotted Vehicles) control systems operating in X-Band.

It should probably provide ordinary pulse amplitude modulation too so that pure chirp simulation could come from one box.

4. 70 MHz Super-Flat FM Modem for FDM

For 4 and 6 GHz MLA work
Optimized for group delay and differential G.D.

This 70 MHz will need a double up-conversion using perhpas 2900 MHz to get through the 11.7 band. It should incorporate latest thinking on MLA improvements. Use PMR-4 strategy.

5. Fast Rise Pulse Modulation Head

This would be a PIN-Line type pulser of the 8403/8730 variety. Probably a smaller PIN-line series would make sense but the 8403A generator still meets most of the pulse applications I know of. Peak pulse detection for levelling (ALA 8670) would be useful.

10ns Rise Time
5µS to 100µS pulse width
10 to 10000 PPS

6. Phase Modulation Diagnostic Head

Similar to other phase mod modems except it would provide demodulation down to bit-streams to allow diagnostics of transmitters and signals.

Considerable innovation should be used on this pair so that phase mod diagnostics can be done. For example, if a differential modulator component could be installed in an operating receiver line which could synchronously insert controlled-phase test pulses in the presence of regular traffic it would be a powerful tool.

The demodulator would then synchronously pull out the test pulses and check their BER differentially. Maybe the demod could also do an "Eye" diagram scope display or a dynamic vector-scope or something similar.

The Santa Rosa spectrum analyzers strategy should work in here but I haven't quite figured how. Possibly the same band-generator serves as the down converter L.O.

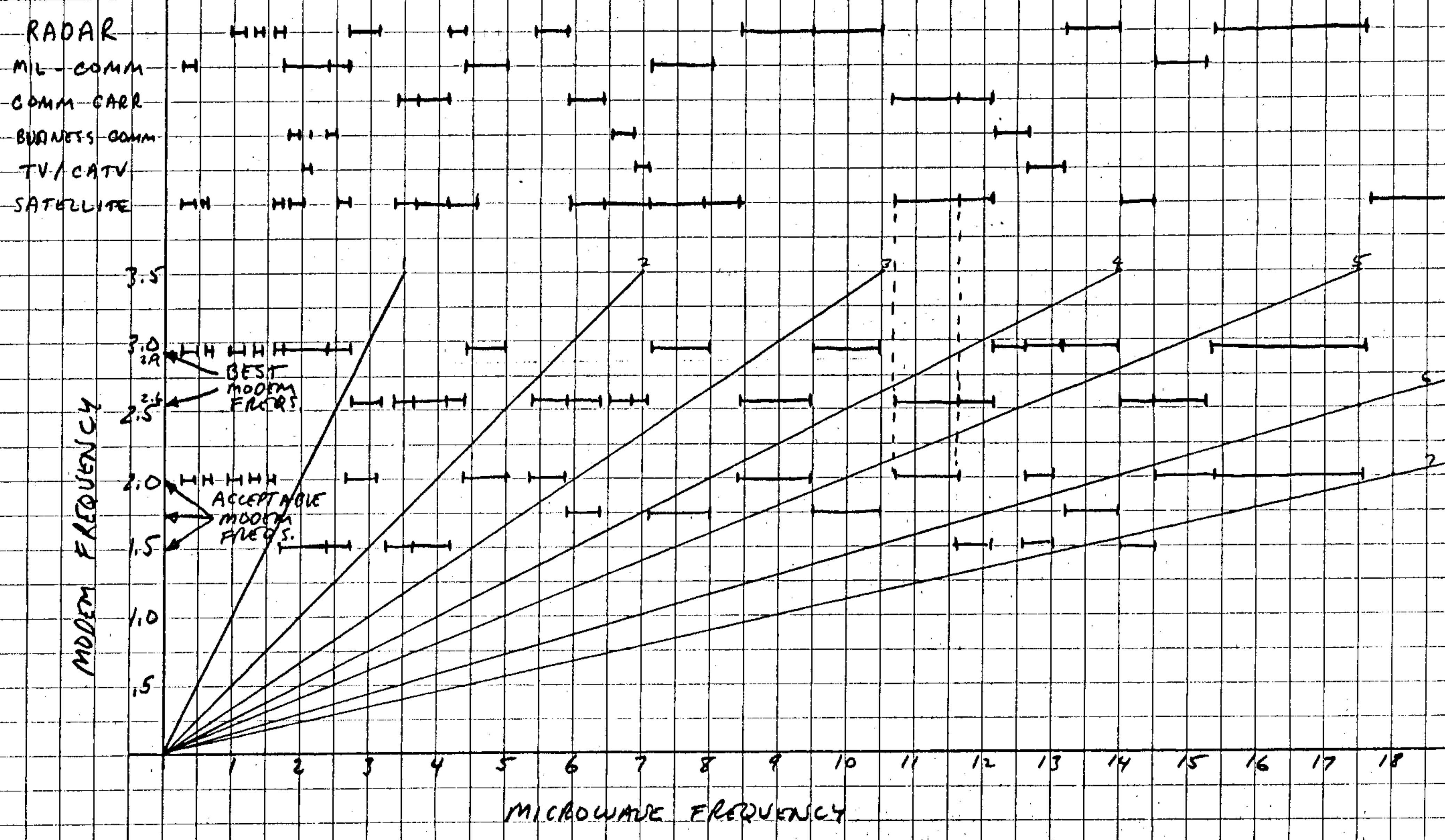
III. <u>A Family of Plug-in Market/Band-Oriented Filters</u>

1. A series of bandpass filters cut for allocated bands ±2 x IF. These would be modular and plug-in to the band-generators. In some cases, several switched filters might be desired.

2. For certain narrower-band applications and especially in A.T.E., a tunable YIG which tracks the modem offset would plug into the filter module.

3. A non-filtered version would be useful for receivers which already use substantial preselection filters such as comm systems.

SELECTING MODEM FREQUENCIES FOR APPLICATIONS BANDS



I've attached a chart showing most band-assignments from 1-18 GHz divided by market use. Since the most troublesome interfering signals in up-conversion are modem harmonics, I placed the various narrow bands into two pairs of modem assignments. The pair with least trouble used model up-conversions at 2600 and 2900 MHz.

A second possibility (with more switching) could cover all bands with modem switched to 1500,1750 and 2000 MHz. It might be easier to build the conversion set at 1.5 and 2 GHz rather than 2.5 - 3.0. However, the 2.5 and 3.0 would probably be more effective at 18-30 GHz bands which I have not shown. The 18-23.6 band would be very important to a 500MBIT QPSK modem. N.E.C. and N.T.T. are already operating there.

This modem concept allows the use of <u>any</u> signal source as an L.O. Thus a synthesizer or 618 could be used. But by innovative product design, we can make a combined package very attractive.

1. Direct frequency readout with modem offset.

2. Controlled, levelled, specified outputs from an integral attenuator. Attention to leakage.

3. Cavity-quality, low-noise signals

4. Ø-lock stable, L.O.

5. Integrated design for band-oriented filters and tracking YIG filters.

Specifically, the design of a combined package gives HP an excellent product differentiation. (The old compatible plug-in game). In addition, specialized versions, and perhaps test-set combinations could be envisioned. Some real innovations could be made.

Market Size

The market for signal generators above 1000 MHz is a big one. The problem is that the variety of applications bands and modulations makes it too hard to make each generator general-purpose enough.

Our old klystrons calibrated old magnetron radars pretty well but basically never were very useful for microwave comm except for L.O. service on the bench. Now, even good pulse mod with our PIN lines isn't good enough.

Here is an approximate count on worldwide population of generators.

	HP Type	HP Population	Est. Non-HP & MIL	Est. Total
L-Band 1-2	614A, 8614A/B	9790	12000	21,790
S-Band 2-4	616A/B, 8616A/B	10650	14000	24,650
C-Band 4-8	618A/B/C	6962	8000	14,962
X-Band 8-12	620A/B	6080	10000	16,080
KU-Band 10-15	626A	1750	1500	3,250
15-21	628A	2000	1500	3,500
		37,232	47,000	84,232

I estimate that the heavy military bands (S and X) have many MIL-spec generators from low bidders. Also, our 618 and 620 have not been competitive in recent years. There has been more overseas competition in L and S but not above. The total is impressive.

Since this population count goes back 20+ years, some of the early kylstrons have undoubtedly been replaced by sweepers and synthesizers. But most are still band-oriented, applications, and the advent of multi-band sweepers and synthesizers won't affect the count very much.

Worldwide Population	84000
Retired or Replaced by Sweepers	20000
	64000

Possible Potential for replacement by modern generator (50%)	32000
Replace over 5 years	6400/yr.
Achievable by HP (50%)	3200/yr.
	250/mo.
Present Forecast	125/mo.
	375/mo.
Projected @ $5,000	$22.5 Million/yr.

Action

I propose an I-number project be established immediately to evaluate the following:

1. A basic technical analysis of signal purity possibilities, with up-conversion techniques.
2. A bench breadboard of a medium data rate phase modulator of perhaps 100MBIT. To explore mixer balance and filtering problems.
3. A chirp modem experiment to evaluate spectral problems involving the filters.

Answers to these questions will allow a better structuring of the final project. Considerable information might come from this project useful to the spectrum analyzer projects.

John L. Minck
6-17-74