stayed within 0·58 Å, which was corresponding to the modulation bandwidth including third harmonics of the modulation signals. These values were small enough as compared with 4 Å of direct modulation of MQW DFB laser.[2] The error rate characteristic after transmission through 100 km of fibre is shown in Fig. 2. There was no power penalty at the receiver in spite of the large dispersion of 1700 ps/nm. High-speed and narrow-spectral characteristics of the EA modulators were confirmed from the transmission experiments.

Conclusion: The superior transmission characteristics of the GaInAsP electroabsorption modulator were confirmed for the first time by the transmission experiments with no power penalty at 2·4 Gbit/s over 100 km of conventional optical fibre. The insertion loss of the modulator will be further reduced by adopting a buried heterostructure, or monolithic integration with a semiconductor laser. These results suggest that the EA modulators have advantages of practical use in multi-Gbit/s and long-haul optical fibre transmission systems.

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TIME DELAY SPREAD MEASUREMENTS AT 850 MHz and 1·7 GHz INSIDE A METROPOLITAN OFFICE BUILDING

Indexing terms: Radiowave propagation, Radio links, Mobile radio systems, Interference

Time delay spread and signal level measurements were made in a multistoried office building in New York City at 850 MHz and 1·7 GHz. No significant statistical difference in time delay spread was found at the two frequencies. The maximum root-mean-square time delay spread at both frequencies did not exceed 100 ns. Attenuation was very nearly the same at the two frequencies, within the limits of the experiment's accuracy.

Introduction: The radio frequency band of operation of future personal communications systems is yet to be determined. An estimation of radio propagation within buildings at different frequencies is vital towards this determination.

The root-mean-square (RMS) time delay spread of the impulse response of the radio channel can be related to intersymbol interference produced by the channel.[1,2] Intersymbol interference limits the usable digital signalling rate in the medium for a given error rate. The first measurements of time delay spread at three office buildings and two residences were reported earlier by Devasirvatham.[3–6] In these studies, conducted at 850 MHz, RMS time delay spreads under 100 ns were consistently measured within the buildings when there was a direct path between the transmitter and receiver. Where there was no direct path, RMS delay spreads of as much as 250 ns were seen. On inside-to-outside paths in two residences and a medium-sized office building, RMS delay spreads were again under 100 ns when there was a good direct path. RMS delay spreads of up to 420 ns were measured where there was no direct path.

This letter reports the results of the first measurements conducted at both 850 MHz and 1·7 GHz, inside a business office building.

Experiment: The experiment to measure the impulse response of the radio propagation channel has been reported in detail.[4,5] It follows the principles of an earlier measurement in the mobile radio environment.[7] Briefly, an 850 or 1700 MHz carrier, biphase-modulated by a 40 Mbit/s pseudonoise code, is broadcast by a transmitter. The signal suffers time smear in the propagation channel and is then correlated at the receiver with an identical pseudonoise code, running 4 kbit/s slower. As the codes sweep past each other, the receiver traces out the power-delay profile of the channel. The system thus acts like a bistatic radar, measuring the (un-normalised) impulse response of the medium. In this implementation of the experiment, only the envelope of the power-delay profile is recorded. The area under the curve gives the received power level, while the square root of its second central moment is the RMS time delay spread.

The transmitter output power was +26 dBm at 850 MHz and +25 dBm at 1·7 GHz. The transmitting and receiving antennas were wideband omnidirectional units. The transmitter antenna was initially at a height of 2·2 m, but was subsequently lowered to about 1·5 m.

At every measurement location, the receiver antenna was rotated through a horizontal 1·2 m (4 foot) diameter circle, at a height of 2 m, while eight equally spaced power-delay profiles were obtained around the perimeter of this area. 2048 points, representing either 2048, 4096 or 10 240 ns of the power-delay profile depending on the timescale, were digitised and stored, after verifying that there was no signal at greater time delays. The eight individual profiles were then power-averaged at each time delay to calculate an averaged power-delay profile.

A normalised averaged power-delay profile at 850 MHz is shown as the solid curve in Fig. 1. The broken curve shows the averaged profile at 1·7 GHz at the same place, taken

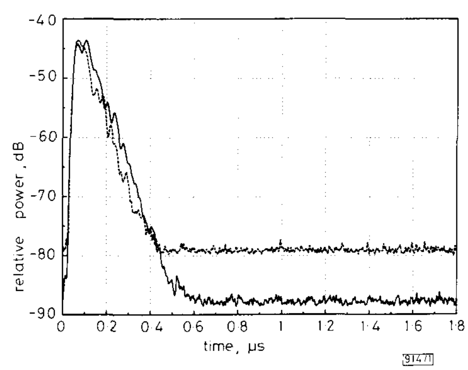

Fig. 1 *Averaged power-delay profiles at 850 MHz (solid curve) and 1·7 GHz (broken curve)*

immediately afterward. Each curve has been separately normalised to the peak power value of a power-delay profile received at that frequency at a reference distance of 0·3 m in free space. This corrects for frequency-dependent system parameters such as transmitted power and antenna gains, and path loss to the reference distance. The two profiles match very closely, indicating that they suffer the same impairments over the multiple echo paths. The higher receiver noise tail at 1·7 GHz is an artefact of the normalisation, since the absolute signal levels were about 9 dB lower at that frequency and hence closer to the noise floor of the receiver.

Subsequently, the averaged power-delay profiles were noise-clipped. The RMS time delay spread as well as the received power were computed.[4,5] The received power levels at each frequency were also normalised by the averaged power received at that frequency at a distance of 0·3 m (1 foot) from the transmitter, to give a measure of the relative path loss at each frequency.

A comprehensive survey of propagation in the building was not attempted in this work. Rather, the aim was to sample the building to see if the results would be very different from the considerable body of measurements reported previously. It was also hoped to obtain a preliminary understanding of the differences in propagation at the two frequencies. Hence, a total of 26 averaged power-delay profiles were obtained at each frequency.

Site description: The site of the experiment was an office building occupying a short city block in mid-town Manhattan in New York City. It is an eight-floor building and measures 61 m × 61 m at the base. Each floor of the building is partitioned into two wings (North and South) by sheet rock walls. Each wing is approximately 26 m × 42 m and is partitioned into cubicles by 1·5 m-high partitions using metal frames covered with cloth. The cubicles are arranged in clusters with walkways between them. The interior walls of the building are made of sheet rock. The exterior walls are a combination of metallised glass and brick siding. The glass areas are covered with closely spaced metallic venetian blinds.

All the measurements were made on the 4th and 7th floors. The 4th floor had higher cubicle partitions and a larger number of metallic cabinets scattered over the area.

Results: Fig. 2 shows the cumulative distributions of RMS time delay spread measured inside the building at the two frequencies, for all locations measured. The RMS delay spread did not exceed 100 ns at either frequency. This is much less than the worst-case results in other buildings, but is equal to the maximum delay spread measured previously when there was a line-of-sight path between the transmitter and receiver. Because of the layout of this building, most data were indeed line-of-sight. However, every effort was taken to provide other cases, by positioning the transmitter in conference rooms and in individual suites separated from the main area by walls. Yet the worst-case results still resemble the direct path results. This seems to indicate that the interior walls and partitions are quite transparent at these frequencies.

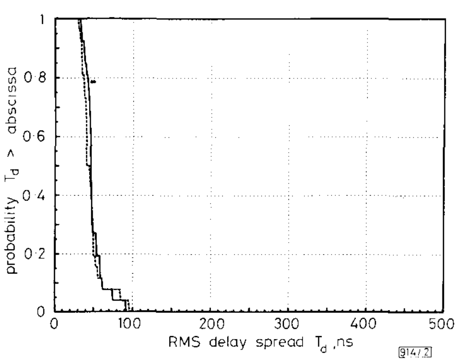

Fig. 2 *Cumulative distributions of RMS time delay spread at 850 MHz (solid curve) and 1·7 GHz (broken curve), for all data (building: OFC/NME)*

Fig. 3 shows the RMS time delay spread at 1·7 GHz plotted against the RMS time delay spread at 850 MHz at the same positions of the transmitter and receiver. The circles represent data taken on the 7th floor, while the crosses show the 4th floor data. The solid curve is the regression line through all the points. The regression results are shown in Table 1.

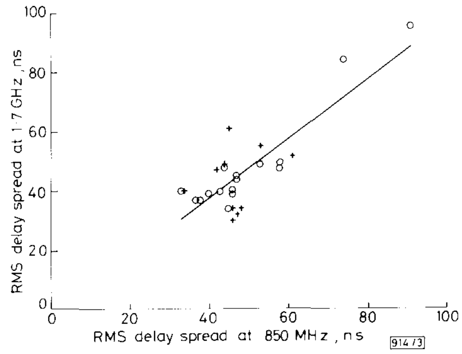

Fig. 3 *RMS time delay spread at 1·7 GHz plotted against results at same locations at 850 MHz*

Regression line for all data is also shown; building: OFC/NME
○ 7th floor   + 4th floor

The 4th floor delay spread data are clumped together over a small range. Hence, regression analysis is not meaningful.

In the above results, the deviation of the regression lines from the origin is small, and is well within the range of the experimental error and the statistical variability in this small sample. The slope can be taken as 1. This implies that the RMS time delay spreads at the two frequencies are statistically the same in this building.

Table 1 DELAY SPREAD REGRESSION

Data	Slope	Intercept	Correlation
		ns	
All data	1·00	−2·7	0·83
7th floor	1·08	+6·0	0·94

Similarly, the path losses at the two frequencies, relative to the losses at 0·3 m, were compared. It was found that these were also statistically equal. Hence, for the purposes of designing a communications system within this building, there were no significant differences in radio propagation, to the first order.

Summary: Time delay spread and signal level measurements were made at 850 MHz and 1·7 GHz inside a business office building in New York City. The relatively open construction and low absorption of the interior walls, coupled with the strongly attenuating exterior walls, kept the RMS time delay spread under 100 ns. Furthermore, RMS time delay spreads measured at the two frequencies were statistically equal. Received power levels, relative to the power at 0·3 m separation, were also equal at the two frequencies, to a first order.

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TUNABLE MAGNETOSTATIC-WAVE OSCILLATOR EMPLOYING A SINGLE GaAs MMIC CHIP

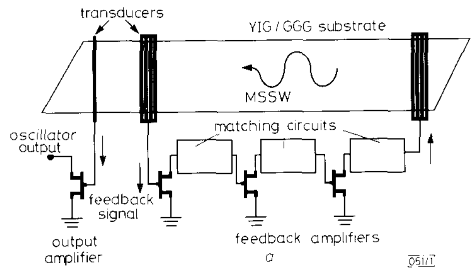
Indexing terms: Microwaves devices and components, Microwave oscillators, Magnetostatic waves, Integrated circuits

A microwave tunable magnetostatic surface-wave delay-line oscillator which employs a single GaAs monolithic amplifier chip in the feedback loop has been developed. No directional coupler is needed, and a single-mode oscillation can be tuned continuously from 4·82 to 6·39 GHz without frequency jumping. At 6·1 GHz, an output power of 4·4 dBm was measured with a phase noise of −100 dBc/Hz at 10 kHz offset from the oscillation frequency.

Introduction: Magnetostatic surface-wave (MSSW) delay lines have been used in microwave tunable oscillators.[1,2] The use of external amplifiers and directional couplers in these oscillators results in physically large components with long external electrical delays that cause frequent frequency jumping during tuning. We have previously reported on an MSSW delay-line oscillator, using multiple GaAs monolithic-microwave-integrated-circuit (MMIC) chips, which avoids the use of an external directional coupler in the feedback loop.[3] This design utilised planar technology in both the MSSW devices and the GaAs MMICs. However, this oscillator had narrow tunable range and multimode oscillation. This letter describes a new MSSW oscillator using a single GaAs monolithic amplifier chip which displays single-mode oscillation over a wide frequency range.

Oscillator design and fabrication: Fig. 1 shows the schematic diagram of the oscillator and a photograph of the GaAs chip. The GaAs circuit consists of a three-stage amplifier which provides the gain needed in the feedback loop. The output and the input of the amplifier are connected to four-finger narrowband transducers for the MSSW delay line. These multiple-finger transducers are used in order to realise single-mode oscillation. Each finger is 2 mm long and 25 μm wide with 25 μm spacings between fingers; the distance between the narrowband transducers is 2·5 mm. The oscillator signal is coupled to the gate of an output MESFET with a single-finger transducer and the output is obtained from the drain of this MESFET. This single-finger transducer is 50 μm wide and is positioned at 1 mm from the narrowband transducer of the delay line. The gate length and width for all the GaAs MESFETs are 1·5 μm and 300 μm, respectively. Silicon nitride capacitors are used between stages for DC blocking and microstrip lines are used for impedance matching. The chip size is 5 mm × 3·5 mm.

To realise the oscillator, a gallium gadolinium garnet (GGG) substrate with 100 μm-thick yttrium–iron–garnet (YIG) film is placed on top of the transducers. A 250 μm gap between the YIG film and the transducers is provided by alumina substrates supporting the GGG substrate. External chip capacitors are used for DC bypass but no bondwires or external components are needed in the microwave path.



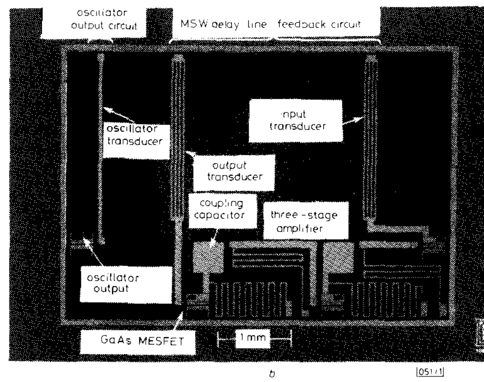


Fig. 1 *MSSW delay line oscillators using single GaAs chip*
a Schematic diagram of oscillator
b Photograph of GaAs MMIC chip

Experimental results: A magnetic field parallel to the YIG film and perpendicular to the direction of MSSW propagation is applied by an electromagnet. Fig. 2 shows the output of the oscillator, measured by a spectrum analyser. The oscillation frequency is 5·54 GHz with a magnetic field of 1244 G. The drain biases for the feedback and output amplifiers are 3·2 V and 2·6 V, respectively. The spectrum shows a very low phase noise, −100 dBc/Hz at 10 kHz offset, which compares favourably with YIG-sphere oscillators.[1] The oscillator maintains this low phase noise for the entire tuning range.

The oscillation has a single mode and the frequency can be tuned continuously from 4·82 GHz (1030 G) to 6·39 GHz

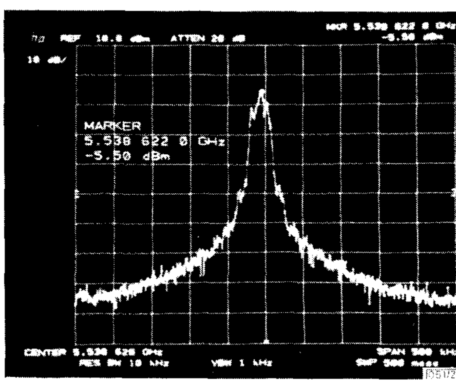


Fig. 2 *Measured oscillator output using spectrum analyser*
Oscillation frequency = 5·539 GHz, frequency span = 500 kHz